

Implementing Reliability Centered Maintenance (RCM) with State of the Art PT&I Technologies

IMC 2016 Abstract

Since President John F. Kennedy's proclamation in May 1961 that "*this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon,*" Kennedy Space Center (KSC) has been at the forefront of NASA's Manned Spaceflight Program.

From Project Mercury to Gemini to Apollo to the Space Shuttle Program and International Space Station (ISS), KSC has continued to evolve and support hundreds of manned and unmanned scientific missions. KSC's evolution as the nation's premier spaceport continues today supporting the Space Launch System (SLS) as well as numerous commercial companies.

As NASA's Ground Systems Development and Operations (GSDO) Program supports the modernization of KSC facilities and equipment, the need for cost-effective and reliable systems becomes paramount. KSC is accomplishing this by conducting efficient maintenance embracing Reliability Centered Maintenance (RCM) processes supported with Predictive Testing and Inspection (PT&I) technologies.

Building on the work that was started two decades ago, Jacobs Space Operations Group has utilized state of the art PT&I technologies to assess the current condition of the assets they manage under the Test and Operations Support Contract (TOSC). Specifically, the Asset Management department leveraged the benefits of ultrasound technology to quantify a motor issue in the Liquid Oxygen Storage Area, and troubleshoot the sources prior to loading the tank to perform Verification and Validation (V&V) activities. This technology was efficient, easy to implement, and provided system engineers with data on a possible source of the problem.

In situations where legacy motors are exhibiting unexpected noises, it may seem easier to remove and refurbish the motor and replace the bearings because that solution resolves most of the common causes of the noise. However, that solution would have involved additional spending and may not have solved issues stemming from the foundation, if those existed. By utilizing the ultrasound equipment provided by UE Systems, the sound profiles allowed Jacobs TOSC team to determine that the issue resembled a faulty bearing. After replacing the bearing, the unexpected noise ceased.

This was the first time portable ultrasound equipment was used to determine maintenance actions for the LOX motors, and the equipment provided the information necessary to make a data driven decision that ultimately achieved the most cost-effective solution.

As technology evolves, sharing information and keeping an open mind with new technology provides the users with the opportunity to conduct their operations more easily and efficiently.

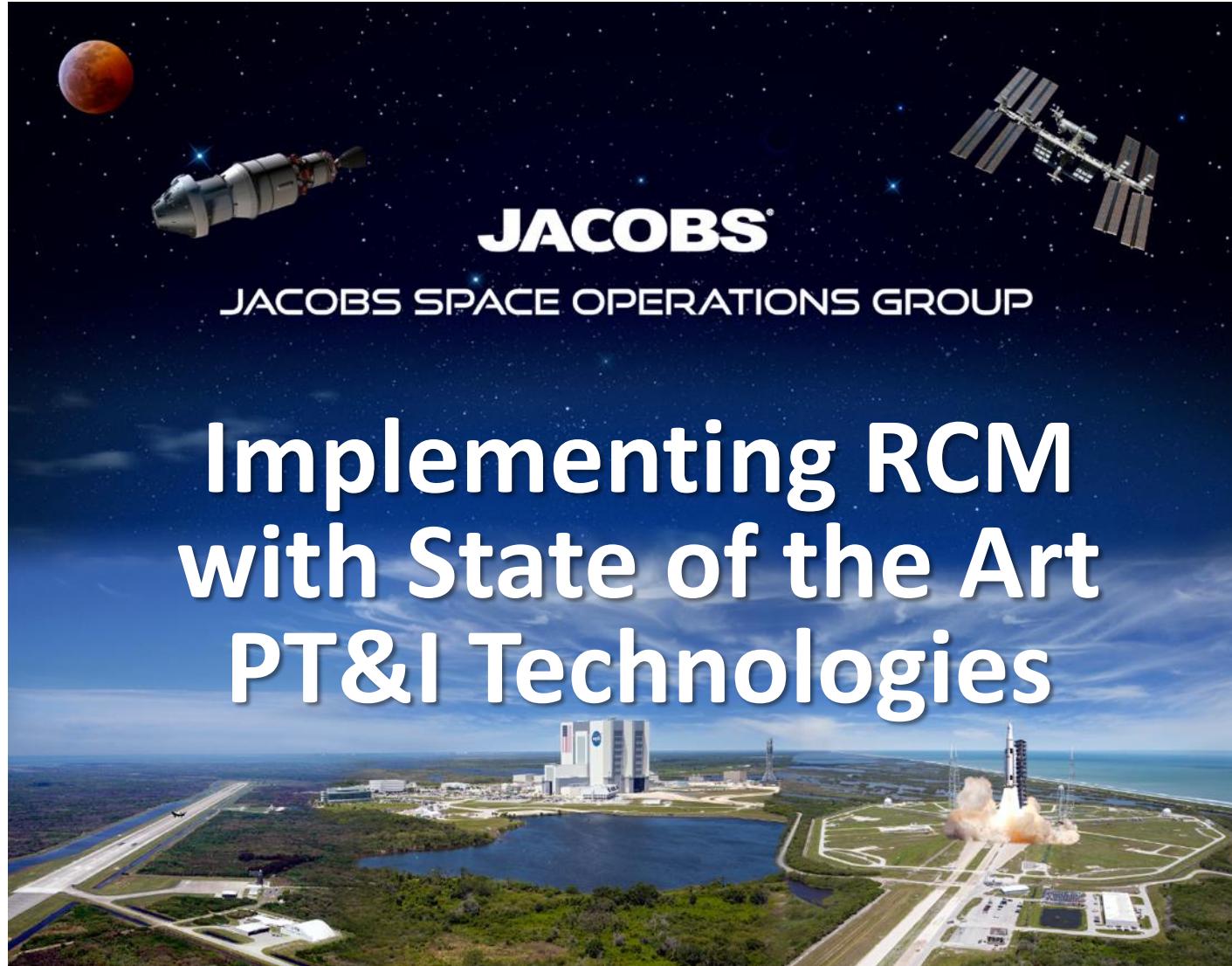
Three takeaways

1. Tools like Ultrasound are cost-efficient and easy to implement, yet provide high return on investments (other examples are finding air leaks, etc.)

2. Keep an open mind when implementing the tools (there's potential for multiple implementation methods)
3. Share, share, share – share your stories, listen to others' stories and learn from these experiences.

Presentation Outline

1. An introduction to KSC and the assets/equipment we own.
2. Data and findings from tests we have performed.
3. RCM in general and how technology can make maintenance more efficient and cost effective.



Implementing RCM with State of the Art PT&I Technologies

Chase Sasser

- UE Systems (4 years) - Southeast Regional Manager
- Academy Sports & Outdoors in hunting & fishing retail sales

Things about me:

- Golf*, Fishing, College Football Tailgating
- World Domino Champion

- Founded in 1973; 40+ years experience with ULTRASOUND
- Corporate Office & Manufacturing Facility in Elmsford, NY
- Direct Corporate support; 15 regional offices in US

In the United States:

- ✓ South Carolina
- ✓ Alabama
- ✓ Texas
- ✓ Colorado
- ✓ California
- ✓ New York
- ✓ New Jersey
- ✓ Michigan
- ✓ Minnesota
- ✓ Missouri

Internationally:

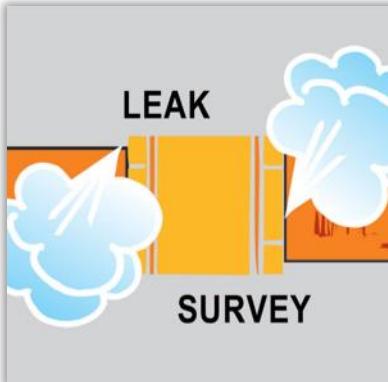
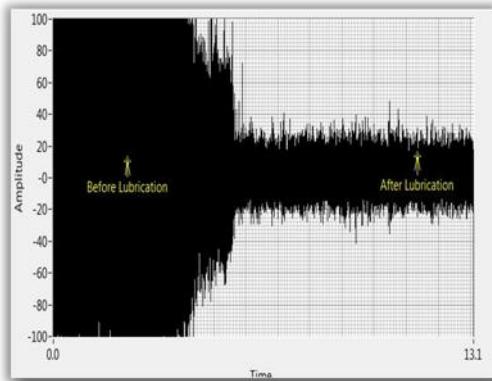
- ✓ Canada
- ✓ Mexico
- ✓ Latin America
- ✓ Amsterdam
- ✓ Hong Kong
- ✓ India
- ✓ Egypt
- ✓ 200+ Corporately supported Distributors

- Ultrasound can be easily implemented to established maintenance & reliability programs that are currently using other technologies such as vibration & infrared
- The best M&R programs are ones that do not rely on one single technology, but multiple technologies

- Ultrasonic Ultraprobe range is 20kHz to 100kHz
- Normal human hearing is 20 Hz to 20 kHz, with average upper range about 16.5 kHz.
- Unit of measurement is a decibel (dB)
- Advantages:
 - Very directional
 - Easy to locate sources of ultrasound
 - The Ultraprobe hears ultrasounds above normal plant background noise
 - Multiple Applications

Structure-Borne Applications

- Bearings
- Valves
- Pumps
- Steam Traps
- Gearboxes
- Lubrication
 - Under/Over



VS.

Airborne Applications

- Compressed Air/Gas leak detection
- Vacuum leaks
- Heat Exchangers
- Electrical Inspection
 - Corona
 - Tracking
 - Arcing

- Prioritize your equipment based on an asset catalog & asset criticality assessment
- Some equipment needs more frequent testing than others
- Set up schedules based on your “criticality index”: likelihood of breakdown, consequences if it fails, safety, cost to repair, etc.
- If vibration routes are already in use, model your ultrasound routes after your vibration routes

When Inspecting Bearings...

- Try to make it as repeatable as possible
- Touch test points at same angle
- Compare similar bearings
- Maintain frequency when comparing
- Confirm diagnosis
- Be Consistent!

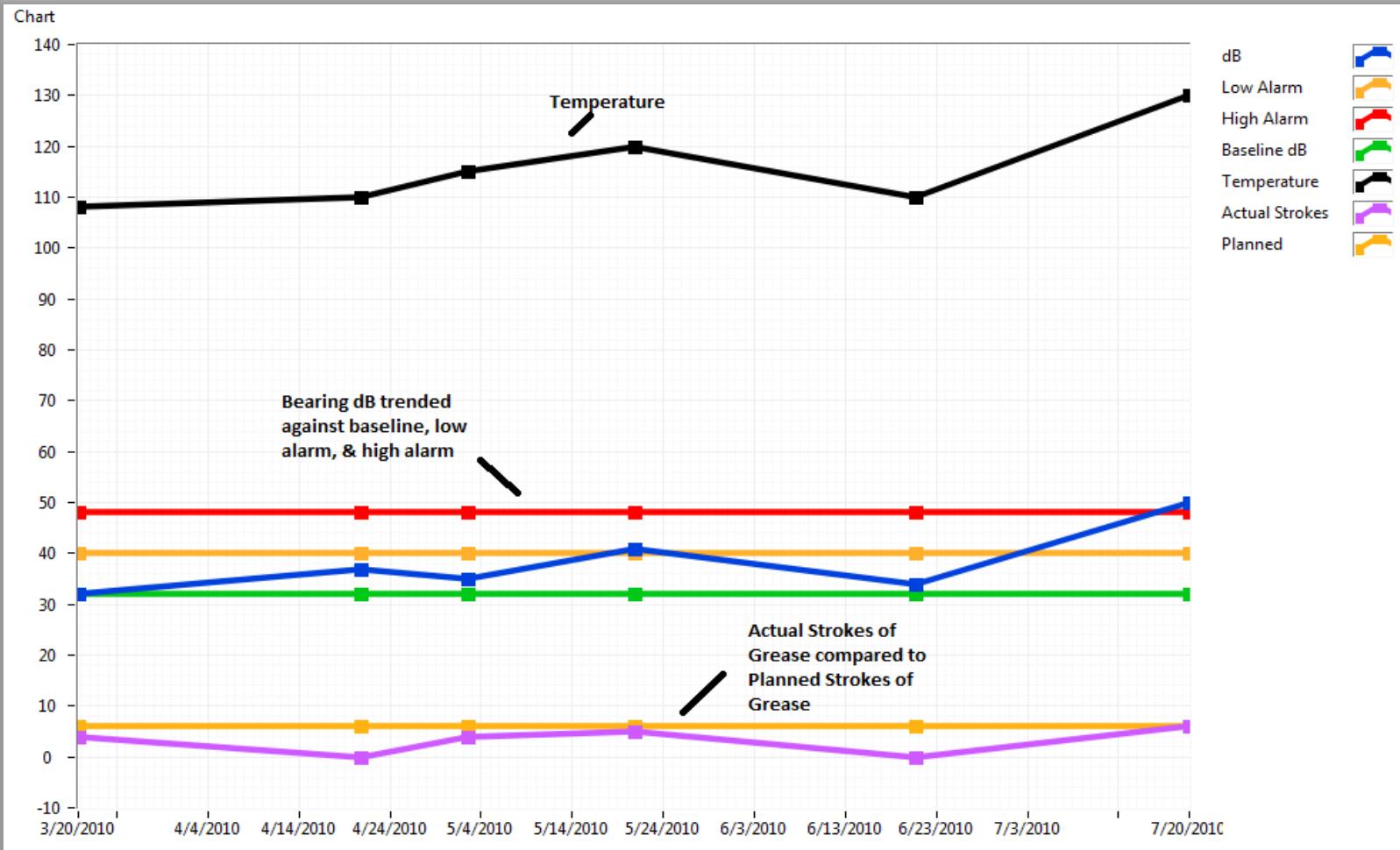


The Historical Method

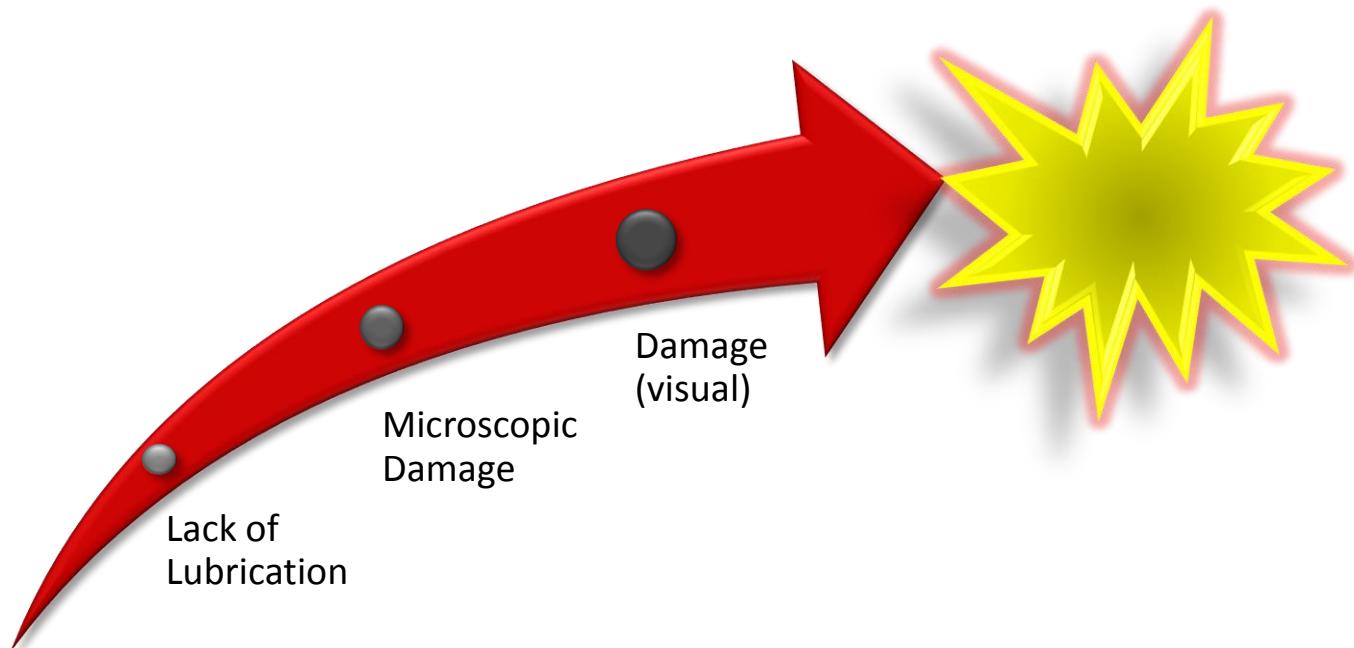
- Create the route in the ultrasound software
- Upload the route from the software into an ultrasound instrument
- Acquire the data
- Record both dB and sound files
- Download data back into the ultrasound software

- Once several readings have been taken (history) & baselines have been set, set alarm levels using standard delta values for failure modes
- Compare baseline sound files to alarm level sound files
- Trend & Report
- Review data from prior months/years

The Historical Method



- 8 dB Lubrication
- 16 dB Damage-Visual Faults
- 35+ dB Severe Failure



- The majority (~60%) of premature bearing failures are lubrication related
- Traditional lubrication programs are time based
- How was the amount of grease applied determined?
- Using ultrasound we can determine when we have applied enough grease & when we have began to over lubricate
- Source of the ultrasound is *friction*

Using ultrasound while greasing will:

1. Let the lubricator know when they have applied enough grease
2. When/If they have begun to over lubricate
3. If there is anything else wrong with the bearing

Good Scenario:

- Lubricate equipment according to manufacturer's recommendations
- Consult with lubricant supplier to ensure that the correct lubricant is being used
- Determine frequency of lube based on equipment run time & operating conditions

Better Scenario:

- Continue on time based lube PM's, but implement an ultrasound instrument to listen to the bearings while applying lubricant
- At least this will let the lubricator know when to stop applying grease
- Other problems will be found
- **Very typical to see a reduction of at least 30% in grease consumption*

Best Scenario:

- Use an ultrasound instrument with data collection capabilities to record both decibel level and sound files
- Establish baselines & alarm levels
- Lubricate equipment with an ultrasound instrument once a data point is in the low alarm or lack of lubrication condition
- Apply lubricant until the decibel decreases back to the baseline dB
- A follow up inspection should be done after lubricating to ensure that the dB remained at the baseline
- A new sound file should be recorded and compared to the original baseline sound file

Sean Hollis

- Jacobs Space Operations Group, Test and Operations Support Contract (TOSC), KSC
- Maintenance and Reliability Engineer: Analysis of the performance of the TOSC Maintenance Program, PT&I Technology support
 - Founding Chair: SMRP Condition Based Monitoring SIG
- Previous positions under TOSC: Mechanical Systems Engineer for the Liquid Oxygen group, Project Management, and Mechanical Design Engineer on fluid/pressure systems
- Interests: Baseball, backgammon master, and any activities on the water

Even though you think you're in a safe configuration,
check...



Background of Jacobs at KSC

- Jacobs provides long-term engineering, scientific, and technical services at seven major sites for NASA
 - Our partnership with NASA dates back to the Mercury Program and has increased dramatically within the last half decade
 - 600 to more than 5,000 professionals solely dedicated to supporting NASA programs
- In December 2012, NASA awarded the Test and Operations Support Contract (TOSC) to Jacobs
 - Teammates include ERC and Aerodyne Industries
- Jacobs is providing overall management and implementation of ground systems capabilities, flight hardware processing and launch operations



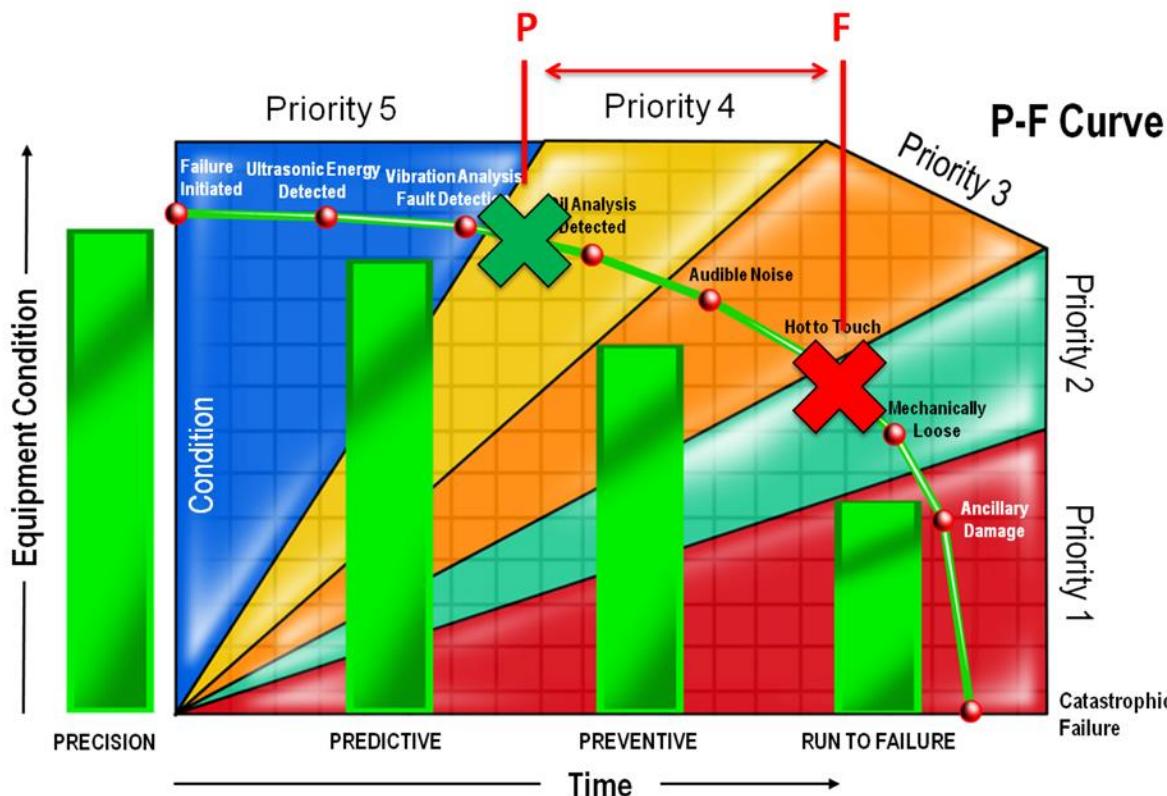
A process used to compile, assess and recommend the most cost-effective and applicable maintenance techniques to minimize the risk and impact of failure in facility and support equipment and systems.

- The objectives of RCM are:
 - To **obtain and sustain** the required inherent safety and reliability levels of the equipment.
 - To **efficiently restore** the equipment to the accepted inherent safety and reliability levels as deterioration requires.
 - To **manage the information** necessary for design improvements of those items in which inherent reliability proves to be inadequate.
 - To accomplish these goals at the **optimal total cost**, including maintenance costs, support cost and economic consequences of operational failures.
- Operator-Based Maintenance and Condition-Based Maintenance

Jacobs performs a variety of preventive maintenance on a wide range of equipment and systems utilizing many PT&I techniques to ensure the equipment works when it is needed:

1. *Oil Sample Analysis*
2. *Infrared Thermography*
3. *Vibration Analysis*
4. *Motor Current Analysis*
5. *Optical Alignment*
6. *Performance Parameter Monitoring*
7. *Ultrasonic Testing*

- Expense, easy/quick implementation, early identification



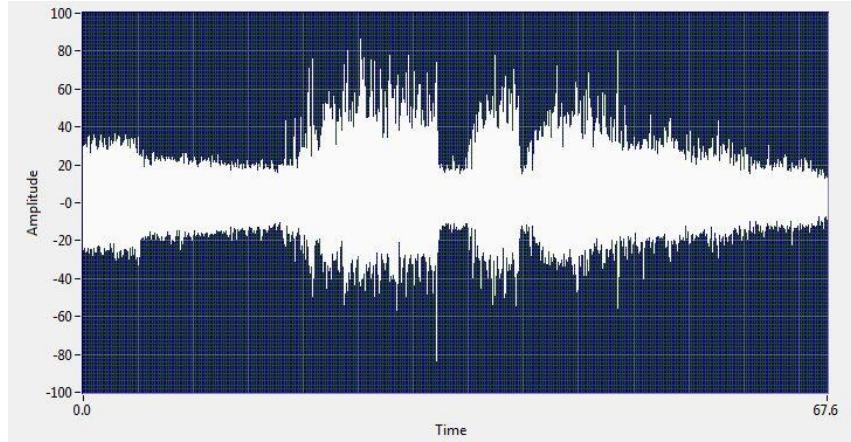
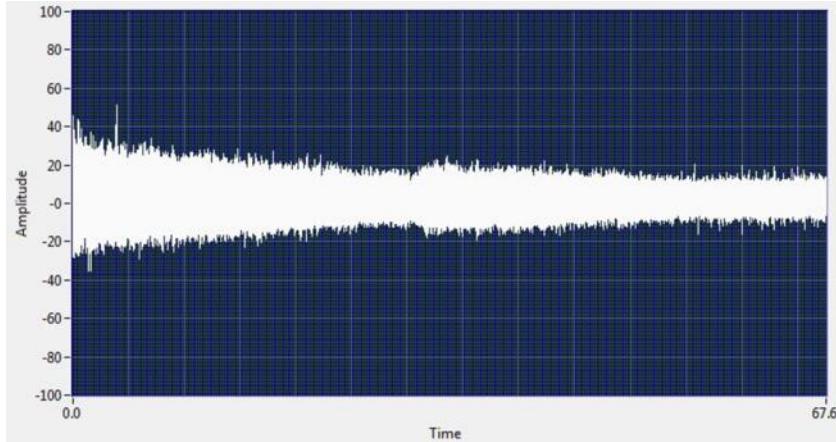
- Necessity for cost-effective and reliable systems
- RCM Guide, PT&I Technologies
- Shift from Flight and Facilities to Ground Support



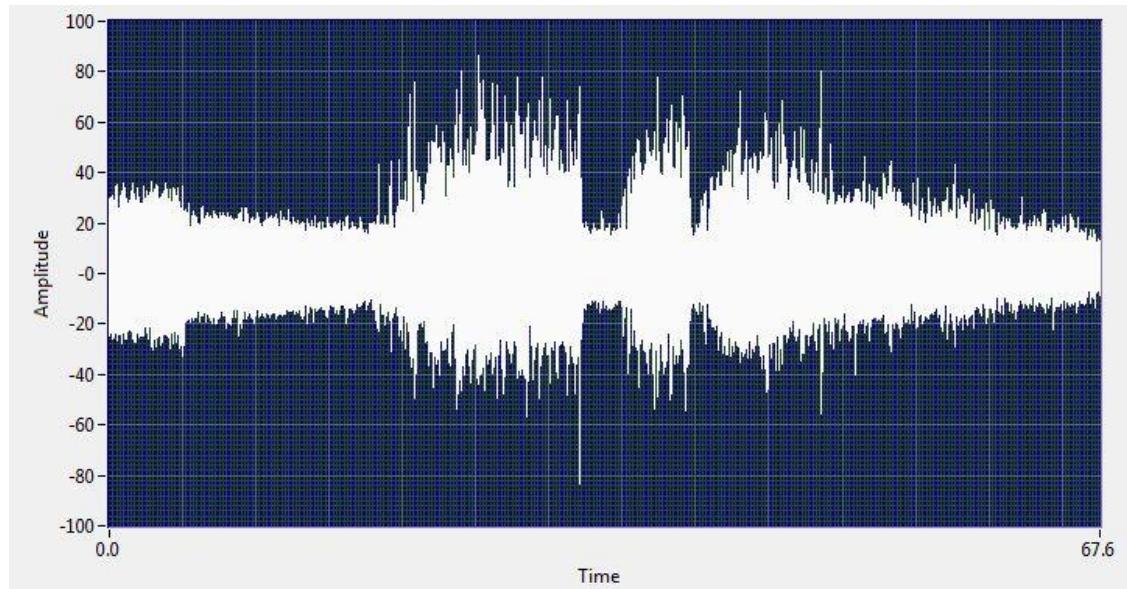
- In the past, there were many motors on the launch pad that were sealed and purged
 - Monthly PMs to bubble soap leak check
- Replace bubble soap leak check with ultrasound surveys
 - Faster
 - More reliable

- During quarterly PMs of running the liquid oxygen motors, the System Engineer heard an unexpected noise
- It was suggested to refurbish the motor because:
 - “It’s an older motor”
 - “It’s easy to refurbish the entire motor because that will solve the problem”





- Top left is the Time Wave form for the coast-down of a motor in good condition from 3600 RPM
 - Signal fairly smooth, no indications of mechanic issues recognized in sound file.
- Top right is the coast-down of an identical motor from 3600 RPM (starting at the first major vertical line on the X-Axis)



- Normal motors would show gradual decrease in intensity over period of time
- This motor shows definite signs of mechanical-related issues

- Best Practice: validate the condition with two technologies
 - Vibration is the recommended technology to collect data in conjunction with ultrasound to validate and trend the condition of the bearing and grease.
- Consider replacing the bearings before flowing liquid oxygen

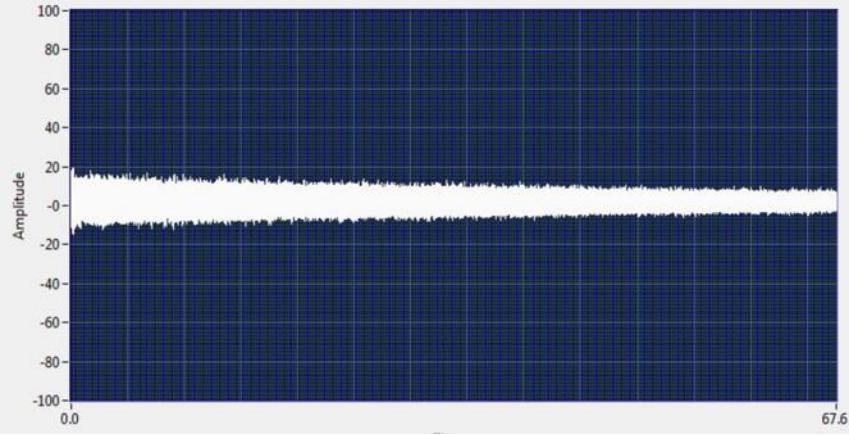
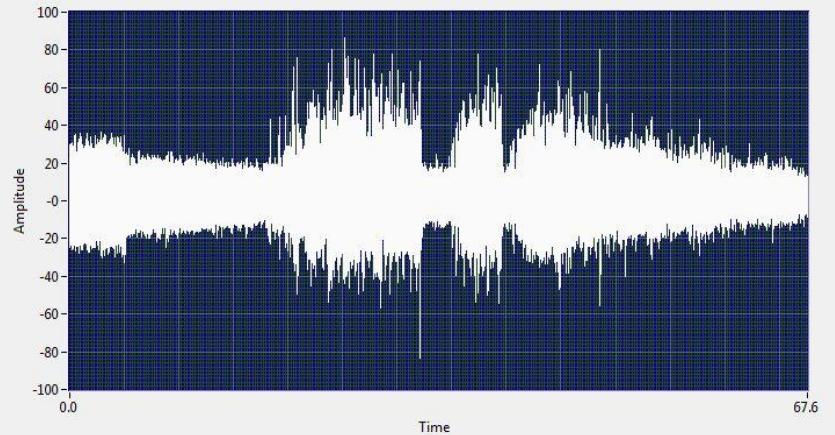
- The ultrasound data indicate the condition of the bearings may be deteriorating
- Upcoming tank fills are required to support Validation and Verification (V&V)
 - During V&V the motors and pumps will need to perform as expected, pumping liquid oxygen for the first time in over 5 years
- Replace the motor bearings and refresh grease prior to these major tasks.
- Continue to support collecting ultrasound files for comparison and trending of the motor bearing and grease condition but at reduced frequency

Images of Damage to Bearings



Images of Damage to Race





- Top Left picture shows coast-down prior to freshening grease and change out of the bearing
- Top Right picture shows the same sound file captured after freshening the grease and bearing change, in addition to PM runs.

- Did not need to refurbish the entire motor
 - Saved processing time and costs to send the motor out to be refurbished
 - Cheaper to replace the bearings, than pay for unnecessary repairs
- System Engineer spends less time troubleshooting and doesn't need to wait on a vendor's backlog for repairs

- Kennedy Space Center is where history is made, and is becoming the World's Premier Spaceport
- Ensuring cost effective reliability through PT&I technologies like ultrasound
- Always looking forward, and utilizing resources available



As Christopher Mears, CMRP of AEDC would say, “The path to maintenance excellence is a journey.” So then “...let’s enjoy this journey together.”



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